An Application of the "Virtual Spacecraft" Concept in Evaluation of the Mars Pathfinder Lander Low Gain Antenna

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The virtual spacecraft concept is embodied in a set of subsystems, either in the form of hardware or computational models, which together represent all, or a portion of, a spacecraft. For example, the telecommunications transponder may be a hardware prototype while the propulsion system may exist only as a simulation. As the various subsystems are realized in hardware, the spacecraft becomes progressively less virtual. This concept is enabled by JPL's Mission System Testbed which is a set of networked workstations running a message passing operating system called "TRAMEL" which stands for Task Remote Asynchronous Message Exchange Layer. Each simulation on the workstations, which may in fact be hardware controlled by the workstation, "publishes" its operating parameters on TRAMEL and other simulations requiring those parameters as input may "subscribe" to them. In this manner, the whole simulation operates as a single virtual system.

This paper describes a simulation designed to evaluate a communications link between the earth and the Mars Pathfinder Lander module as it descends under a parachute through the Martian atmosphere toward the planet's surface. This link includes a transmitter and a low gain antenna on the spacecraft and a receiving antenna and receiver on the earth as well as a simulation of the dynamics of the spacecraft. The transmitter, the ground station antenna, the receiver and the dynamics are all simulated computationally while the spacecraft antenna is implemented in hardware on a very simple spacecraft mock-up. The dynamics simulation is a record of one output of the ensemble of outputs of a Monte Carlo simulation of the descent. Additionally, the antenna/spacecraft mock-up system was simulated using APATC II, a shooting and bouncing ray code developed by Demaco, Inc. The antenna simulation, the antenna hardware, and the link simulation are all physically located in different facilities at JPL separated by several hundred meters and are linked via the local area network (LAN).

The Mars Pathfinder Lander low gain antenna is an azimuthally isotropic short monopole with a small skirt to limit radiation into the lower hemisphere. Thus, it has a pattern null in the vertical direction. The lander mock-up is a truncated three sided pyramid, as represented in

Figure 1, simulating the descent configuration of the spacecraft. The low gain antenna is mounted on a support mast shout 6" long on the lander at the middle of the top edge of one of the petals. The mast is tilted by about 12 degrees inboard placing the phase center of the antenna slightly above the lander as shown. The antenna model was established by matching the far zone pattern of a three element colinear array to the measured free space antenna pattern. This required a complex weighting of 4.0 for the center element anti 0.5 at -135 degrees for the end elements. Interaction of the radiation from the antenna with the spacecraft significantly modifies the pattern. So much so, in fact, that the modulation scheme for the actual flight link had to be modified as a result. An example computed pattern of the antenna when mounted on the mock-Lip is shown in Figure 2a along with that of the antenna alone for comparison. Figure 2b shows the measured pattern of the antenna on the mock-up.

As the spacecraft descends toward the surface beneath the parachute it swings and rotates causing the earth to execute a complicated trajectory through the pattern of the antenna. As mentioned earlier, the dynamics of the spacecraft during this phase of the mission was simulated via Monte Carlo techniques. One sample of the resulting ensemble of trajectories of the earth was selected for this study anti this selected sample is shown in Figure 3.

The link simulation was carried out on the Mission System Testbed. The dynamics record as a function of time published angular coordinates of the earth relative to the lander at a sequence of times. These were used by the antenna simulation (or measurement) to provide corresponding antenna gain anti phase to the link simulation process which computed bit error rate and corresponding errors in the message. Figure 4 shows the calculated antenna gain as a function of time during the descent of the lander. The message was 'peter piper picked a pepper" repeated contiIIuously. Example output of the link for our simulation looks like this. "peter piper pickow w?cnrqperpeter piper picked a pepper peter ..." Note that the errors are localized where the antenna gain drops as one might expect.

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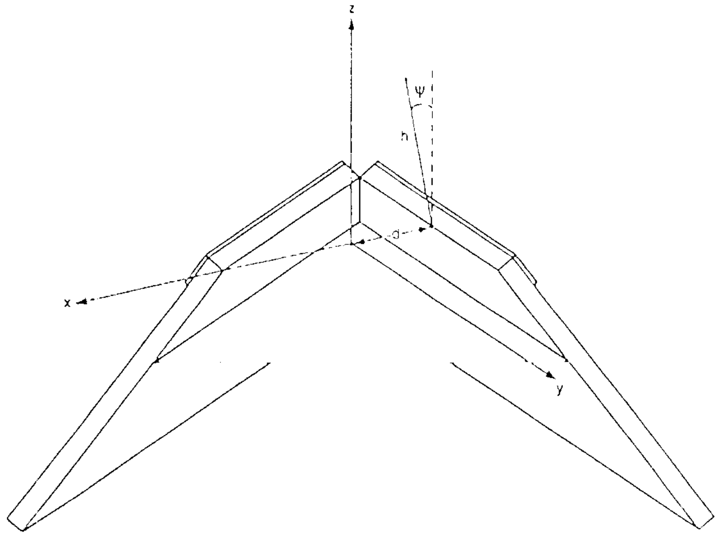

Figure 1. Lander configuration.

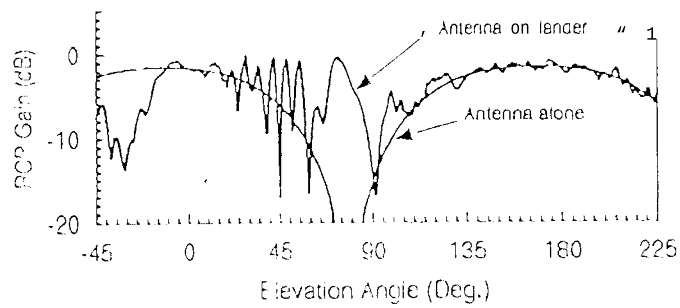

Figure 2a. Computed low gain antenna pattern.

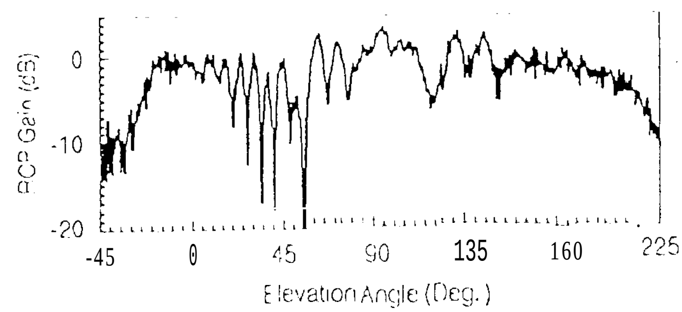

Figure 2b. Measured low gain antenna pattern.

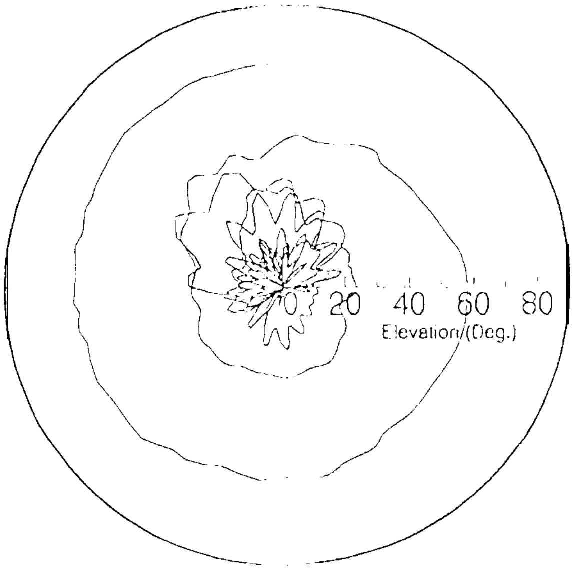

Figure 3. Trajectory of the earth in the field of view of the antenna.

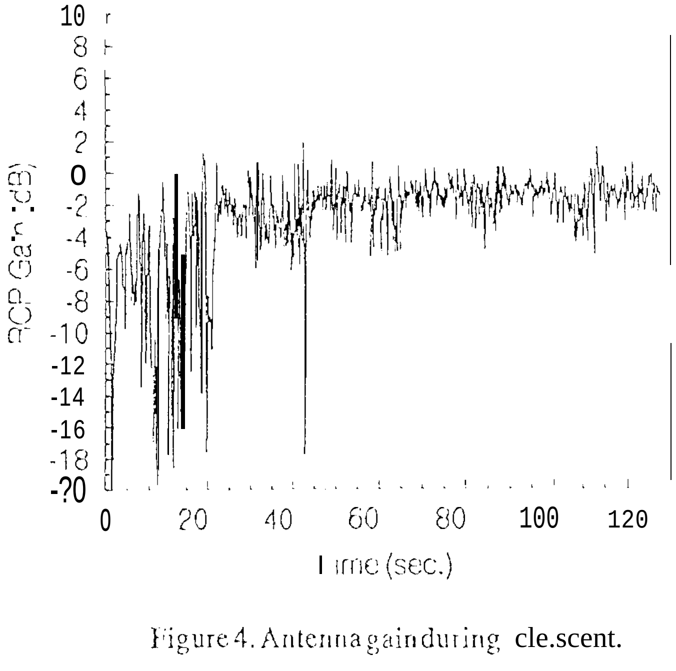

Figure 4. Antenna gain during descent.